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ORIGINAL ARTICLES.

The Genesis of Oligoclase in Certain Schists.

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Introduction.

In a recent investigation of progressive regional metamorphism of the schists of South Westland, New Zealand, the writer [1] observed that the transition from quartz-albite-chlorite-epidote-schists of low metamorphic grade to high-grade quartz-plagioclase-biotite-schists and gneisses is accompanied by a marked increase in the anorthite content of the plagioclase. An oligoclase zone was therefore established to include schists with plagioclase containing 10 per cent or more of anorthite.

In the following discussion the available evidence is examined, with a view to determining the physical and chemical conditions governing the formation of oligoclase in green schists and more or less related quartzo-feldspathic sedimentary schists, and the consequent value of oligoclase as a zonal index in metamorphic rocks of appropriate composition.

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[1] F. J. Turner, "The Metamorphic and Intrusive Rocks of South Westland": *Trans. N.Z. Inst.*, lxiii, pt. ii, 1933, 178 et seq.

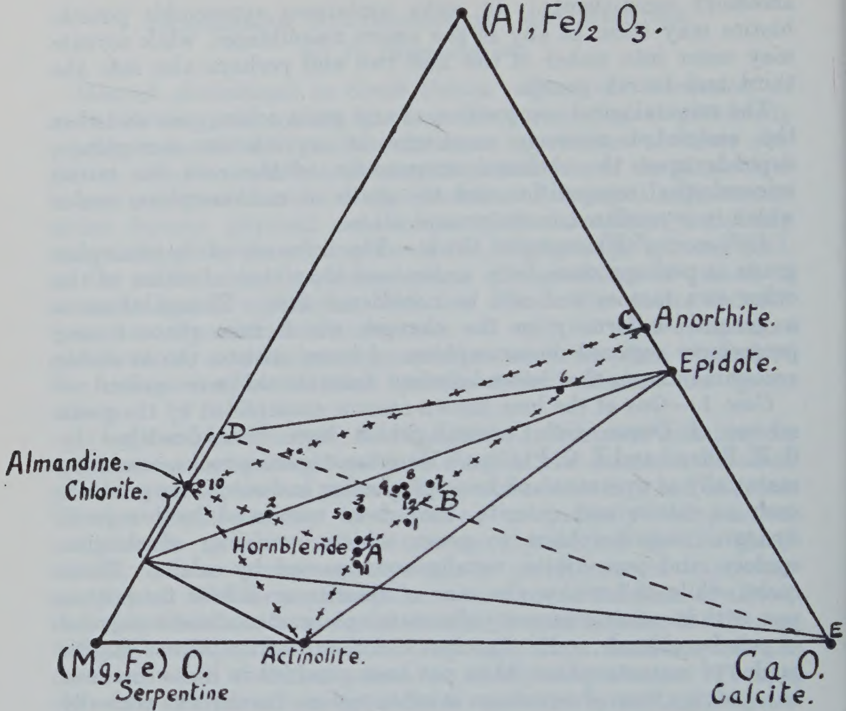

FIG. 1.—Diagram illustrating variation in chemical and mineralogical composition of green schists. The hornblende point A represents the composition of theoretical syntagmatite.

(1) Hornblende–oligoclase–epidote–schist, Prawle Point, Devon (C. E. Tilley, 1923, 186).
(2) Chlorite–albite–epidote–schist, Kurokura-Kannawa, Japan (K. Sugi, op. cit., 103).
(3) Chlorite–epidote–albite–schist, Seacombe Sands, Devon (C. E. Tilley, 1923, 183).
(4) Actinolite–chlorite–epidote–albite–schist, Kurokura, Japan (K. Sugi, op. cit., 109).
(5) Actinolitic chlorite–epidote–albite–schist, Sulitelma, Norway (T. Vogt, op. cit., 316).
(6) Biotite–epidote–albite–schist with small amounts of chlorite, Ballochandrian, Argyllshire (F. C. Phillips, 1930, 254, No. i).
(7) Hornblende–epidote–biotite–albite–schist, Loch Boltachan, Perthshire (F. C. Phillips, 1930, 254, No. ii).
(8) Garnetiferous hornblende–schist, Perthshire (F. C. Phillips, 1930, 254, No. iv)—K_2O calculated as biotite.
(9) The same rock as (8) with K_2O calculated as orthoclase.
(10) Chlorite–albite–schist, Sulitelma, Norway (T. Vogt, op. cit., 323).
(11) Biotite–hornblende–plagioclase–schist, Ardlui, Dumbartonshire (F. C. Phillips, 1930, 254, No. vi.)
(12) Average Basalt (R. A. Daly, *Igneous Rocks and their Origin*, 1914, 27).

system $(Al,Fe)_2O_3$—$(Mg,Fe)O$—CaO may be used to test the relative importance of these two reactions. Aluminous chlorite and calcite in the proportion EB : BD would give syntagmatitic hornblende and anorthite in the proportion CB : BA ; or if the hornblende thus formed should be regarded as a mixture of the tremolite and syntagmatite molecules, the amount of hornblende would be slightly less and the amount of anorthite correspondingly greater than is indicated by this ratio. The relative proportions of the two minerals, as deduced thus from theoretical considerations, correspond closely with those observed by Tilley in the rocks themselves. On the other hand, reaction between chlorite and epidote would produce considerably more anorthite than hornblende (unless only the serpentine molecule of the chlorite were concerned), and furthermore, the epidote would be used up in the process faster than the chlorite. These results are at variance with Tilley's observations, and it is therefore concluded that reaction between chlorite and calcite is mainly responsible for the entry of the hornblende-oligoclase association at this stage in metamorphism. That the epidote does take some part in the process is indicated, however, by the marked decrease in the iron content of this mineral during the change. Possibly the ferriferous molecule of the epidote is more active than the clinozoisite molecule in this respect.

Case 2.—The green schists of the Misaka Series of Japan, recently described in detail by K. Sugi,[1] may be taken as an example of the second case on account of the completeness of the data recorded, even though this instance is complicated by the effects of purely contact metamorphism superposed upon the initial dynamothermal metamorphism. The unaltered rocks are basic lavas, tuffs, and minor diabases, which consist mainly of calcic plagioclase, enstatite-augite and hypersthene, and are almost unaffected by weathering. The characteristic assemblage at the lowest grade of metamorphism is albite-chlorite-epidote, both the two latter minerals being ferruginous varieties. At a somewhat higher grade the green schists are composed essentially of albite (An_6 to An_9), actinolite and epidote, with chlorite in accessory quantity. The iron content of both the latter minerals is less than in the albite-chlorite-epidote schists. Though the actinolite schists represent a higher grade of metamorphism than the albite-chlorite-epidote-schists, the former must not be regarded as derivatives of the latter. The schists of both facies have been derived directly from the initial igneous rocks, so that residual grains of calcic plagioclase and pyroxene may still persist even in the actinolitic schists. Sugi [2] has clearly expressed this in a diagram, from which it may also be seen that the actinolite-bearing schists have crystallized at a somewhat higher temperature than the schists of lower grade, the stress being about the same for both facies. The changes involved may be summarized thus :—

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[1] K. Sugi, " On the Metamorphic Facies of the Misaka Series in the Vicinity of Nakagawa," *Jap. Jour. Geol. and Geogr.*, ix, 1931, 87–142.

[2] Op. cit., 141, fig. 13.

calcic plagioclase + magnesian pyroxene
← →
albite–chlorite–epidote albite–actinolite–epidote–chlorite.

Somewhat similar transformations have been recorded by T. Vogt[1] in the green schists of the Sulitelma area of Norway. Here gabbros and their metamorphosed derivatives have undergone metamorphism of gradually decreasing grade under conditions of falling temperature and approximately constant high stress.[2] The mineralogical changes corresponding to variation of grade between the zones of almandine and chlorite as determined for associated sedimentary schists are as follows :—

quartz–oligoclase–hornblende–epidote.
↓
quartz–albite–actinolite–epidote–chlorite.
↓
quartz–albite–epidote–chlorite.
↓
quartz–albite–chlorite.

Case 3.—A third case related to that just considered is furnished by dynamic metamorphism of greywackes and basic igneous rocks, at low grades without change in bulk composition. Some of the epi-zone schists of Central Otago, New Zealand, display this phenomenon clearly. The unaltered greywackes from which the schists have been derived consist mainly of plagioclase, quartz, and hornblende, often accompanied by pyroxene and fragments of basic rock. By regional metamorphism of the lowest grade within the chlorite zone of associated mica-schists and phyllites, certain of these greywackes show direct transition into schists consisting essentially of albite, actinolite, epidote, chlorite, and quartz, the first three minerals predominating. The grade of metamorphism concerned is distinctly lower than that which governed the crystallization of the actinolitic schists in the previous case. This is indicated by the very low anorthite content of the albite, the frequent occurrence of residual clastic grains of hornblende, quartz, and felspar, and field association with schists of different chemical composition belonging to the lowest grade of the epi-zone. The main reaction concerned appears to be—

green or brown hornblende + plagioclase.
↓
actinolite + epidote + albite + minor chlorite.

Case 4.—The fourth case refers to green schists containing appreciable amounts of potash which appears as sericitic mica in the least metamorphosed members of the group. A detailed account of the effects of progressive regional metamorphism in rocks of this type has been given by F. C. Phillips[1] in a paper dealing with the Green Beds of the Scottish Dalradian. His conclusions may be summarized briefly thus: (1) At an early stage, well within the chlorite zone as defined for pelites, a greenish biotite develops by interaction between chlorite and sericite. Within the zone of biotite, this greenish biotite assumes the normal red-brown tint, presumably due to increase of the FeO content.

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[1] T. Vogt, "Sulitelmafeltets Geologi og Petrografi," *Norges Geol. Undersökelse*, No. 121, 1927.

[2] Cf. A. Harker, op. cit., 271, 272.

(2) Within the almandine zone, deep blue-green hornblende commences to appear, and simultaneously the anorthite molecule begins to enter to a notable extent into the plagioclase, the reaction given being:—

epidote + albite → amphibole + more calcic plagioclase.

In some cases almandine also appears at this stage.

(3) At higher grades of metamorphism corresponding to the zones of kyanite and sillimanite, hornblende becomes very plentiful and the anorthite content of the plagioclase reaches a maximum (between 30 per cent and 40 per cent). At the same time biotite and epidote disappear and amphibolites consisting of green hornblende and andesine with or without garnet are the end-products of metamorphism. Harker[2] has drawn attention to the fact that at this stage the potash together with some soda has entered into the hornblende.

Though the formation of green hornblende and oligoclase is attributed by Phillips to reaction between epidote and albite, it is obvious from Fig. 1 that additional magnesia is required. This is supplied by the excess chlorite surviving from the chlorite-biotite reaction, or perhaps by the biotite itself as it changes to the normal red-brown type. The controlling factor seems to be the instability of the chlorite-epidote association at medium and high grades of metamorphism.

The mutual relationships between the various assemblages may be represented thus—

$$\begin{tikzcd}
 & \text{chlorite–epidote–albite–sericite} \arrow[d] & \\
 & \text{biotite–chlorite–epidote–albite} \arrow[dl] \arrow[dr] & \\
\text{hornblende–biotite–oligoclase–epidote} \arrow[d] & & \text{hornblende–biotite–oligoclase–almandine} \arrow[d] \\
\text{hornblende–andesine} & & \text{hornblende–andesine–almandine}
\end{tikzcd}$$

Influence of Chemical Composition.—In the green schists variation in chemical composition is partially responsible for variation in the course of metamorphism in the four cases under discussion.

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[1] F. C. Phillips, "Progressive Metamorphism in the Green Beds of the Scottish Dalradian," *Min. Mag.*, xxii, 1930, 239–256.

[2] Op. cit., 266, 267, 281.

Tilley[1] and Phillips[2] have demonstrated that the presence of a comparatively high percentage of potash disturbs the normal sequence of events, in that a greenish biotite appears early (within the chlorite zone of pelites) and the crystallization of amphibole (green hornblende) is restricted to moderately high grades of metamorphism. It may therefore be inferred that at the higher grade of metamorphism within the chlorite zone the association chlorite-sericite is even less stable than chlorite-calcite.

The influence of manganese in causing early development of spessartite-bearing garnet in the zone of chlorite has also been discussed fully by Tilley,[3] and as it has no bearing upon the genesis of anorthite need not be considered further.

It was thought that differences in chemical composition might also explain the alternative development of the assemblages albite-actinolite-epidote-chlorite and oligoclase-hornblende-epidote in green schists of comparatively low grade. With this purpose in view, analyses of a number of green schists were plotted for purposes of comparison on the diagram (Fig. 1) representing the system $(Al,Fe)_2O_3$—$(Mg,Fe)O$—CaO. The analyses were first recalculated to give molecular proportions of the constituent oxides, and sufficient alumina to combine with all the soda as albite was subtracted. In schists containing no micas, K_2O was reckoned as orthoclase and a corresponding amount of alumina was deducted. Where green biotite was present the potash was assumed to enter into the latter mineral, and appropriate amounts of the various oxides, as calculated from an analysis of green biotite given by Phillips,[4] were subtracted. The oxides $(Al,Fe)_2O_3$, $(Mg,Fe)O$ and CaO were then recalculated to 100 and plotted.

No very striking difference in composition between the albite-actinolite-schists (Nos. 4 and 5) and the oligoclase-hornblende-schists (Nos. 1 and 7) is indicated, except that the latter seem to be slightly more calcic than the former from the few analyses available. Presumably, then, some other factor is responsible for the existence of these two assemblages at the same metamorphic grade.

Comparison of analyses of Scottish garnetiferous hornblende-schists (Nos. 8 and 9), and a biotite-hornblende-schist (No. 11) from the same region, seems to suggest that low alumina is responsible for the non-appearance of garnet in the latter rock. Whereas the garnetiferous schist lies in the field of anorthite-hornblende-almandine, the biotite-hornblende-schist lies in that of hornblende-anorthite-calcite. The analysis of the latter rock includes 0·91 per cent of CO_2 from which it may be inferred that calcite actually is present in appreciable quantity.

Influence of Initial Mineralogical Composition and Changes in Chemical Composition.—In the chlorite zone green schists containing only a small percentage of potash consist of one or other of the assemblages—

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[1] Op. cit., 199–201.

[2] Op. cit., 1930, 252–3.

[3] Op. cit., 198.

[4] Op. cit., 1930, 255, No. vii.

Chlorite–epidote–albite,
Chlorite–epidote–albite–calcite,
Actinolite–epidote–albite–chlorite,
Pale hornblende–oligoclase–epidote.

Two distinct metamorphic facies are usually recognized,[1] the first two assemblages representing a low grade, and the second two a comparatively high grade of metamorphism.

The writer has endeavoured to show, however, that the actinolite-epidote-albite-chlorite association may arise under a wider range of conditions than has hitherto been recognized, so that the actinolite schists are isogradic sometimes with schists containing pale hornblende and oligoclase and at others with chlorite-epidote-albite-calcite schists. This variation in mineralogical composition of isogradic green schists seems to depend partly upon differences in mineralogical composition of the initial rocks, and partly upon whether or not removal of lime from the system accompanies metamorphism at the lowest grade.

T. Vogt [2] has shown that in the Sulitelma area the ultimate product of metamorphism at low grade, provided no change in bulk composition is involved, is actinolite-epidote-albite-chlorite-schist. The chlorite-epidote-albite-schists and chlorite-albite-schists of this region are formed only when lime is progressively removed from the system. This relation is clearly demonstrated by plotting analyses of the rocks concerned as in Fig. 1 (Nos. 5 and 10). Again, though the actinolite-schists of the Misaka Series described by Sugi [3] appear to represent a somewhat higher grade of metamorphism than the chlorite-epidote-albite-schists of the same series, comparison of the plotted analyses of typical rocks (Nos. 2 and 4, Fig. 1) at once reveals the fact that removal of lime was an essential factor in the crystallization of the latter group of rocks. It is therefore concluded that in general the production of chlorite-epidote-albite-schists by low-grade metamorphism of basic igneous rocks is accompanied by subtraction of lime. In many cases (e.g. in the Start district) carbon dioxide has been present in sufficient quantity to retain the lime set free, in the form of calcite, thus giving the typical assemblage chlorite-epidote-albite-calcite.

In all recorded instances available to the writer, schists consisting of pale hornblende, oligoclase, and epidote appear to be products of progressive metamorphism of rocks which had already crystallized as chlorite-epidote-albite-calcite-schists at a lower grade, the essential factor controlling the reconstitution process being instability of chlorite in the presence of calcite. The plotted analyses of all such rocks lie well on the calcite side of the chlorite-epidote field in Fig. 1.

[1] e.g. K. Sugi, op. cit.; A. Harker, op. cit.
[2] Op. cit.
[3] Op. cit.

On the other hand when there is direct reconstitution of a hitherto unaltered basic igneous rock without change in bulk composition and in the absence of CO_2, the assemblage actinolite-epidote-albite-chlorite is developed. The alternative development of the two amphibole-bearing assemblages thus depends mainly upon the mineralogical rather than the chemical composition of the immediate parent rock.

Low-grade Facies in Green Schists.—Tilley [1] has shown that the green-schist facies of Eskola actually embraces two distinct facies, one characterized by chlorite-epidote-albite and the other by hornblende-oligoclase-epidote. Other writers, e.g. Vogt [2] and Sugi,[3] substitute an actinolite-green-schist facies for the hornblende-oligoclase facies of Tilley.

If the writer's interpretation of the evidence as outlined above is correct, then the chlorite-epidote-albite facies of Tilley, the actinolite-green-schist facies of other writers and the original green-schist facies of Eskola are mutually equivalent, since each of these typical assemblages may exist unchanged at both low and relatively high grades within the zone of chlorite. Tilley's original subdivision of Eskola's green-schist facies may now be modified by admitting calcite as a fourth constituent of the low-grade assemblage, so that two facies may still be recognized, characterized respectively by chlorite-epidote-albite-calcite and pale hornblende-oligoclase-epidote.

(*b*) *In Quartzo-Felspathic Sediments of Related Composition.*

The majority of the schists of South Westland described by the writer are quartzo-felspathic rocks, which are the metamorphosed derivatives of sands resulting from fairly rapid disintegration of basic and intermediate igneous rocks. While they resemble the green schists in the universal presence of a plagioclase felspar, they differ in that quartz and micas are much more plentiful, and chlorite and epidote much less so than in true green schists, while calcite is usually absent even at low metamorphic grades.

Within the chlorite zone and perhaps even beyond the biotite isograd as drawn for pelitic schists, the typical mineral assemblage is quartz-albite-chlorite-sericite-epidote. At more advanced grades within the biotite zone, red-brown biotite is formed in the usual way, by reaction between sericite and chlorite, the latter mineral being completely used up in the process. Simultaneously the iron content of the epidote falls considerably, so that clinozoisite is the typical epidote mineral of the biotite-schists. In the most strongly metamorphosed rocks observed (probably isogradic with pelitic schists of the almandine zone in other regions) the epidote mineral disappears, its place being taken by anorthite which now enters the plagioclase to a notable extent. The characteristic assemblage at this stage is quartz-biotite-oligoclase-muscovite.

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[1] C. E. Tilley, "The Facies Classification of Metamorphic Rocks," GEOL. MAG., LXI, 1924, 167–171.

[2] Op. cit.

[3] Op. cit.

T. Vogt[1] has discussed the genesis of oligoclase at high metamorphic grade in sedimentary schists of the Sulitelma area of Norway, where he has established an oligoclase zone beyond the zone of almandine. The Sulitelma rocks include schists comparable with those of South Westland in addition to more complex types richer in lime or magnesia. The reaction given by Vogt[2] is—

$$\text{Clinozoisite} + Al_2O_3 \text{ (from muscovite)} \rightarrow \text{anorthite} + \text{water.}$$

This reaction, involving subtraction of alumina from the muscovite (and consequent enrichment of this mineral in the phengite molecule) would thus appear to take place in rocks sufficiently rich in potash for muscovite to persist even at high metamorphic grades.

The fact that small amounts of anorthite are held in the albite even at low grades of metamorphism must not be overlooked. The equation epidote + alumina → anorthite appears to represent a balanced reaction, such that in the presence of abundant albite small amounts of anorthite may enter into this latter mineral, and remain in equilibrium with epidote even at low grades when epidote is the more stable lime silicate of the two. As the metamorphism becomes more intense (i.e. as the temperature rises), the percentage of anorthite capable of being held in the albite slowly increases.[3] Thus in the schists of South Westland the composition of the plagioclase changes from a mean value of $Ab_{96}An_4$ in the chlorite zone, to $Ab_{93}An_7$ in the zone of biotite. At higher metamorphic grades the anorthite content of the plagioclase apparently increases much more rapidly, though the data bearing upon this point are as yet too scanty to warrant generalization, beyond recognition of the fact that the composition of oligoclase is attained only at high grades comparable with that which exists in the almandine zone as defined for pelitic schists. The first appearance, in rocks of this type, of plagioclase containing 10 per cent of anorthite may therefore conveniently be used to define a zone of oligoclase.

In the schists of South Westland muscovite is present in excess over the amount required to combine with chlorite to form biotite, so that within the zone of biotite the typical assemblage of minerals is quartz-albite-biotite-muscovite-epidote. Consequently, almandine is never formed at higher grades, and only three zones may be recognized, characterized respectively by chlorite, biotite, and oligoclase.

CONTACT METAMORPHISM.

The occurrence of anorthite in thermally metamorphosed calcareous sediments is well established, and the chemical conditions controlling its formation are sufficiently well understood to be omitted from this discussion. It is enough to state that anorthite is thoroughly stable at high grades of contact metamorphism, and that in rocks initially containing albite it appears as a constituent of oligoclase or andesine at even moderate grades.[1] Aluminous hornblende is also a common constituent of rocks of appropriate composition which have suffered contact metamorphism of medium grade ; at higher grades its place is taken by pyroxenes.

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[1] Op. cit. [2] Op. cit., 432. [3] Cf. A. Harker, op. cit., 93.

When basic igneous rocks, green schists and related quartzo-felspathic sediments such as those of South Westland are thermally metamorphosed at medium grade, mineral assemblages such as plagioclase-hornblende, plagioclase-hornblende-biotite, and plagioclase-biotite-muscovite are therefore readily produced. An instructive instance has been recorded by K. Sugi [2] who has discussed the effects of contact metamorphism upon green schists which had previously crystallized as chlorite-albite-epidote-schists and actinolite-albite-epidote-schists under dynamothermal influences. Within the contact aureole these rocks pass into amphibolites consisting essentially of green hornblende and calcic plagioclase. Exact data referring to quartzo-felspathic sediments such as have been considered in this discussion, are not known to the writer. However, in a recent account (now in the press) of the metamorphic rocks of the extreme south-west of New Zealand, W. N. Benson and J. A. Bartrum have described quartz-andesine-biotite-hornfelses, which they believe to be products of purely contact metamorphism upon quartzo-felspathic rocks comparable with those of South Westland.

It is therefore safe to conclude that the reactions resulting in the genesis of anorthite and hornblende during dynamothermal metamorphism of rocks, such as we have been considering, also take place readily during contact metamorphism of moderate grade. Under high stresses such as prevail in the epi- and meso-zones of dynamothermal alteration, no doubt a higher temperature is necessary for the formation of these minerals than that which is sufficient to bring about their genesis under purely contact conditions when stress is low.[3]

SUMMARY.

The mineralogical changes in green schists and related quartzo-felspathic schists of sedimentary origin are discussed, and the following conclusions are reached as to the conditions of formation of oligoclase in these rocks :—

(1) Oligoclase normally appears as a product of dynamothermal metamorphism at relatively high grades such as prevail in the zones of almandine and perhaps kyanite. It is accompanied either by deeply-coloured hornblende, hornblende and biotite, or biotite and muscovite, according to the chemical composition of the rocks in which it occurs.

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[1] A. Harker, op. cit., 93.

[2] Op. cit.

[3] Cf. Harker, op. cit., 212, 230.

(2) Sodic oligoclase containing 10 per cent to 15 per cent of anorthite may occur with pale aluminous hornblende in green schists lying within the more strongly metamorphosed portion of the chlorite zone. The rocks in question are low in potash and have been formed by reconstitution, at a higher grade, of chlorite-epidote-albite-schists containing calcite. This oligoclase-hornblende association is not to be confused with the actinolite-epidote-albite-chlorite assemblage which is formed at any grade within the zone of chlorite, by direct reconstitution of basic igneous rocks without change in bulk composition and in the absence of CO_2. A slight modification of Tilley's subdivision of the green schist facies of Eskola is therefore introduced.

(3) A zone of oligoclase representing a grade of metamorphism higher than that attained in the biotite zone, may be recognized for quartzo-felspathic schists of appropriate composition and for many green schists, in areas of progressive regional metamorphism. In the latter case, blue-green hornblende often accompanied by biotite is also present.

(4) Oligoclase or more calcic plagioclase and deeply-coloured hornblende form readily during purely thermal metamorphism of only medium grade in the absence of stress. This accounts for the irregular distribution of both these minerals in districts where purely thermal and regional metamorphism have both occurred during the same period of orogeny.

Coastal Changes in South Wales—The Excavation of an Old Beach.

By Leonard S. Higgins, M.A.

WHILE investigating the problem of coastal changes in South Wales, and examining[1] the area of the Merthyr Mawr Warren (Fig. 1) for this purpose, the differences, observable in the surface conditions to-day, and evident in the records of the past, between the areas east and west of a line approximating to the Burrows Well stream, suggested that the relatively recent physical history of the two sections of the area had not been similar. The greater width in the east suggested recent accumulation in this section, and the presence of what appeared to be successively formed littoral dunes pointed to a relatively recent phase of prograding, while the topography made it possible that these changes were related to the mouth of the River Ogmore.

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[1] The series of levels and the excavations referred to were carried out with the permission of Colonel J. I. D. Nicholl and Mr. Lewis D. Nicholl, to whom the writer is much indebted. The writer is also under obligation to Mr. Edward Loveluck, A.R.I.B.A., and Mr. Roderick G. Williams, of Bridgend, for much advice and assistance and also to the former for the loan of valuable instruments.

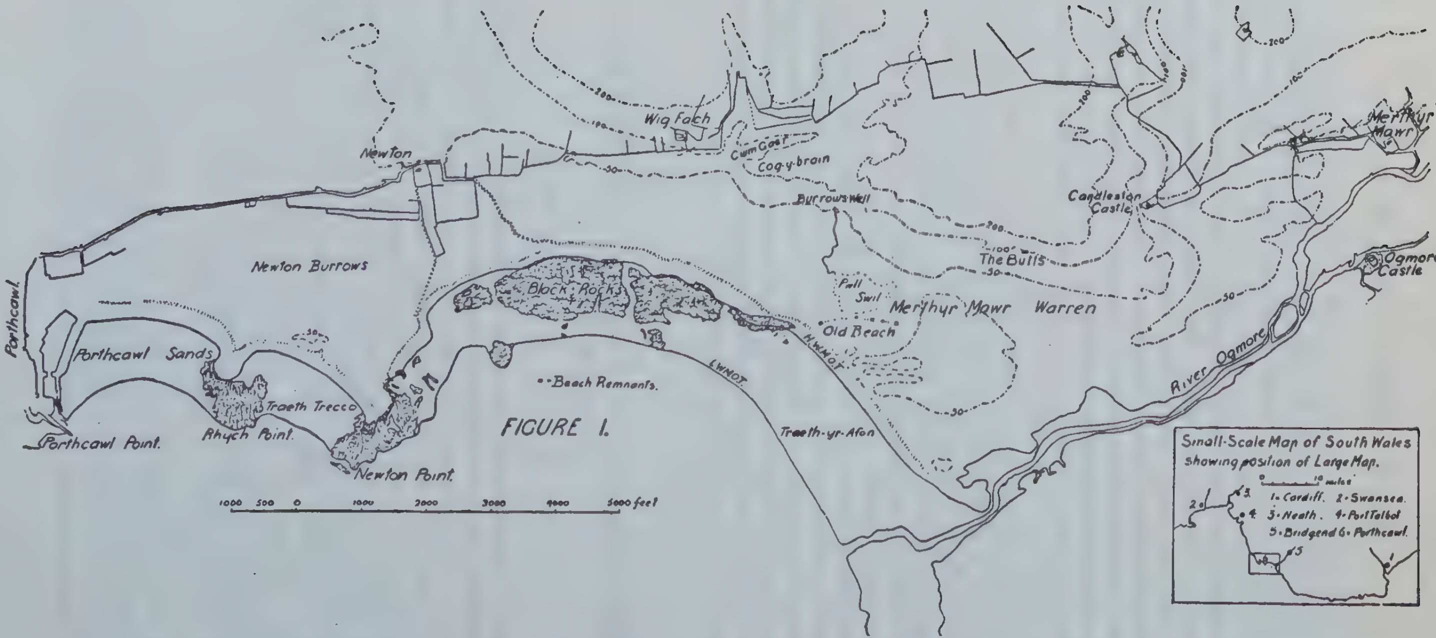

FIG. 1.—Map showing position of Beach. Based upon the Ordnance Survey Map with the sanction of the Controller of H.M. Stationery Office.

A careful search in the low areas within the dunes revealed towards the west five structures of varying size, apparently of artificial formation, and separated by considerable intervals of blown sand from under which they protruded.

A traverse survey of these structures showed them to form part of an arc of slight curvature (Fig. 4), and when plotted on the Ordnance map (Fig. 1) they continued the line of the outcrop on the beach, known as the Black Rocks, in a way which suggested that they were in some way related to it (Fig. 1).[1]

The largest and best preserved (No. 2 from the West) was opened by digging a 3 ft. trench through it for a distance of more than 50 feet. This showed the interior to be formed of alternate layers of sand and stone, dipping approximately at uniform angles in the direction of the sea, and of such a character as to suggest that it was part of the upper portion of a beach which once existed here. The interior is shown by a vertical section (Fig. 2).[2] The stone present was almost entirely Carboniferous Limestone and Triassic conglomerate, and the form and size of the individual pieces indicated that they had not travelled far from their original source, while an examination under the microscope of samples taken from the sandy layers revealed the presence of fragments of marine shells in beds 2 and 4. This structure was clearly a remnant of the upper portion of a beach which once existed at this spot.

The other four structures were similarly opened, No. 3 from the west, the next best preserved carefully, and the others, which appeared only in small and scattered pieces, less carefully. All except No. 1 were similar in structure to No. 2, and therefore showed that they had each formed part of the same old beach. No. 1 of which the remains were very small and scattered lay, unlike the others (which lay upon sand), on an old land surface, and showed that the beach had hinged to this old surface at this point.

A cross section through each remnant, except No. 1 which occurred in patches too small and isolated to permit of this being done, showed that in each case the inner margin sloped downward to lower ground, and this slope, for varying distances, had on its surface stone similar to that which formed the upper stone layer of the seaward slope (Fig. 3). A longitudinal section, constructed after running a line of levels[3] along the series, revealed the fact

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[1] No adequate map of the area existed, i.e. one contoured to show the sand-hills and having the few landmarks which are present among them marked on it, and owing to the difficulty of carrying heavy instruments over long distances of difficult ground, the fixing of sand-hills and sites within them upon the map was carried out with a prismatic compass and a box-sextant, the angles of the latter being used on the spot to check the bearings of the former.

[2] In order that the angle of dip of the different beds, and their relationship to the surface should be accurately shown the top of one side of the trench was levelled through with a dumpy level, and the beds inserted on a section after the outline of the structure had been plotted.

[3] All the levelling in connection with this work was carried out by means of a dumpy level.

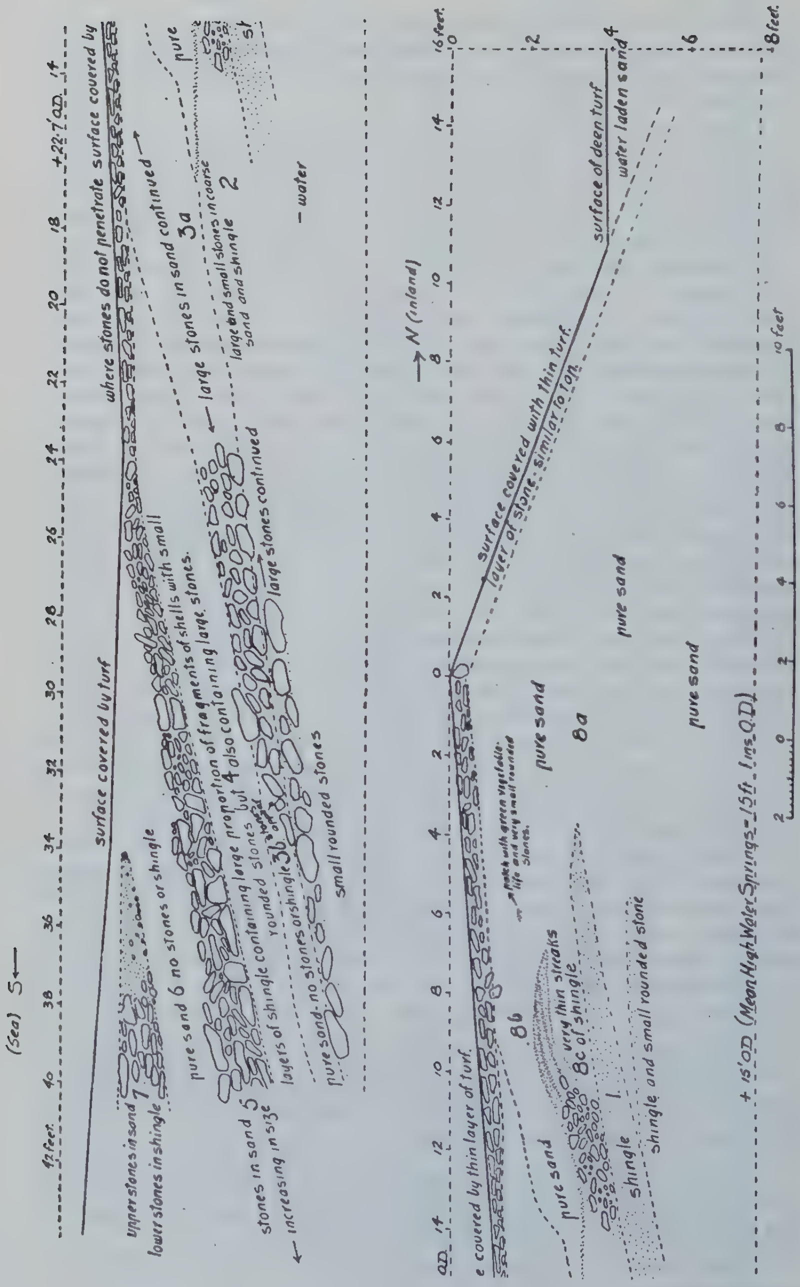
(Sea) S←
42 feet
40
38
36
34
32
30
28
26
24
22
20
18
+22·7' O.D. 14
surface covered by turf
where stones do not penetrate surface covered by
upper stones in sand 7
lower stones in shingle
pure sand 6 no stones or shingle
stones in sand 5
← increasing in size
layers of shingle containing large proportion of fragments of shells with small
rounded stones
but 4 also containing large stones.
3b
pure sand · no stones or shingle
small rounded stones
large stones continued
← large stones in sand continued →
3a
pure
large and small stones in coarse sand and shingle
2
St
— water
→ N (inland)
O.D. 14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16 feet
0
2
4
6
8 feet
e covered by thin layer of turf.
surface covered with thin turf.
layer of stone: similar to top.
surface of deep turf
water laden sand
patch with green vegetable life and very small rounded stones.
pure sand
8a
pure sand
pure sand
8b
very thin streaks
8c of shingle
pure sand
1.
shingle
shingle and small rounded stone
+ 15' O.D. (Mean High Water Springs = 15 ft. 1 ins. O.D.)
2
0
2
4
6
8
10 feet
horizontal and vertical scale

FIG. 2.—Vertical Section through Relic No. 2.

that they did not all lie at the same height, and that they were lowest at No. 2 and rose towards the west (No. 1) and towards the east (No. 5) by 7 feet and 1 ft. 8 in. respectively (Fig. 4).

The structures were clearly isolated and accidentally exposed remnants of an old shore-line which ran eastward in a slight curve from remnant No. 1 to some point beyond remnant No. 5. It is not possible to make any statement as to the extent eastward of this old shore-line for any remains which exist in this direction lie beneath huge accumulations of blown sand. The excavations revealed no evidence as to its age, and apart from fixing certain limits of time beyond which it could not have been formed, the only possible sources of information on this point lay in the question of the relationship of the old shore-line to the present sea-level, in the form and character of its deposits, and in its relationship to the remainder of the coast. It lay, to the east of remnant No. 1, upon sand, and, as will be shown later, approximated to the present sea-level, and could only have been formed after the completion of the so-called Neolithic subsidence.[1] The stone present in the remnants had not been carried far from its source, the alternation of layers of sand and stone suggested that the latter had been derived by lateral movement from an area of rocky coast lying beyond its limits when formed, and the direction of long-shore drift along this coast placed such a source to the west. The evidence derived from the deposits which formed the remnants therefore all pointed to the old beach having been formed by long-shore drift, to the source of the material having been rock outcropping to the west, and to the conclusion that this beach was not formed until after the rocky part of the coast in the neighbourhood of Porthcawl had reached much of its present position. With regard to the source of this material it is possible to go further than this. It consisted entirely of Carboniferous Limestone and Triassic conglomerate, and since the Black Rock outcrop, which lies immediately contiguous with the old beach on the west and forms a continuation of its alignment in this direction, is faulted and is formed of the former rock to the west and the latter to the east of the fault, this outcrop is undoubtedly the source of the material. Finally there is evidence that at the completion of the Neolithic subsidence, the coast-line in this neighbourhood lay beyond the present site of Tusker,[2] and that it only reached its present position after a considerable amount of material had been eroded inland of this rock. This old beach therefore could not have been formed until after the Neolithic subsidence had been completed.

With regard to the problem of the relationship of this old shore-line to any estuary of the River Ogmore which might have previously existed, the evidence derived from the stone present in it shows the

[1] This was dated by the late Clement Reid as about 1500 B.C., see *Submerged Forests*, p. 22.

[2] A rock lying just over 1½ miles S.W. of the mouth of the River Ogmore.

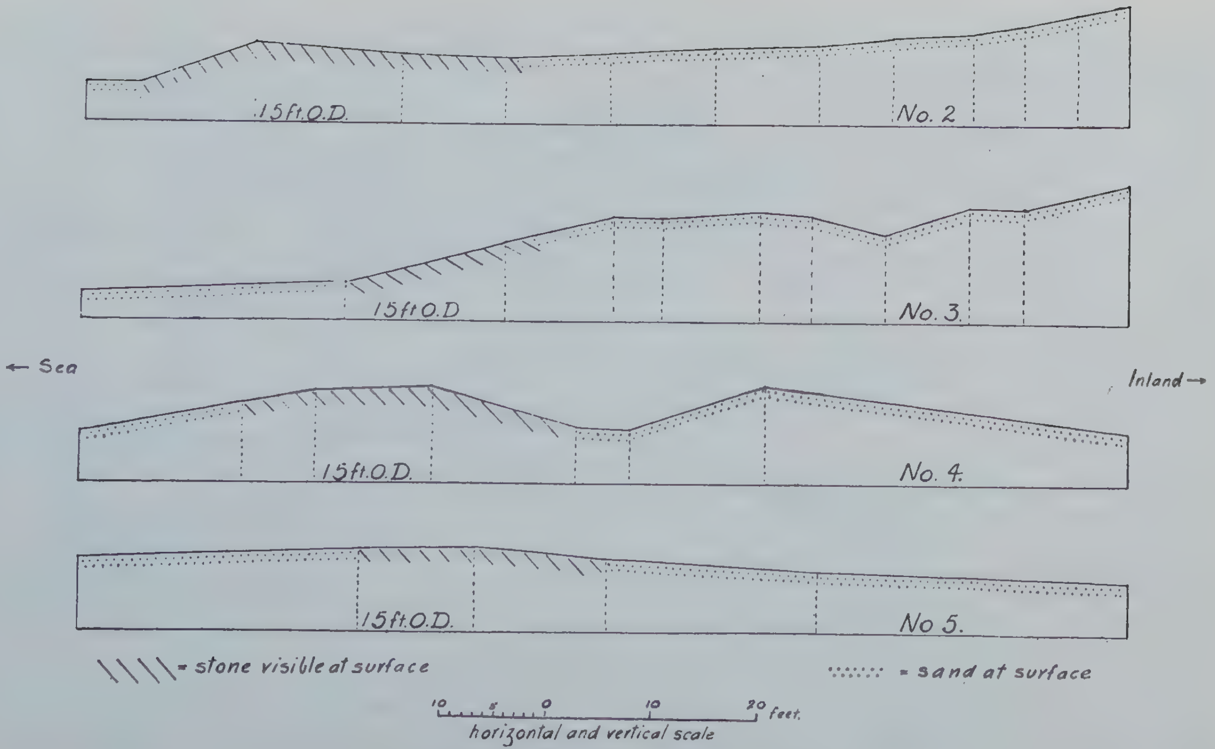

FIG. 3.—Cross-sections through Remnants.

beach to have been produced by material supplied from the west, and as a result of forces acting from the west, while the presence of marine shells in the beds of sand show that these deposits accumulated in marine and not estuarine waters.

The subsequent history must have been one of conflict between the forces of destruction and protection. The lower portions have been protected everywhere from the sea by accumulations of sand similar to those overlying them, while the upper portions must at times have been completely buried and protected by the deposits of wind-blown sand, which except in five spots still cover them completely. The destructive forces have been most active in the neighbourhood of relic No. 2, where the flood waters of Pwll Swil together with the sea, which penetrates here during severe storms when accompanied by very high tides,[1] have removed much material from the rear, and also exposed a large area to the erosive action of the wind. The removal of this material from behind must have caused the upper portion of the beach to collapse landward, and the stone, not being subject to removal by the wind, has remained on the surface of the inner slope. In this way the longitudinal section and transverse profiles shown in Figs. 4 and 5 must have been produced.

The remnants of the old beach provided a unique opportunity for the investigation of changes in the relative levels of land and sea since its formation. This involved establishing the relationship of the relics to the present tide-level, and necessitated the relating of their levels to both Ordnance datum and Admiralty datum in the locality. Fly-levels carried across the dunes from a bench mark near Candleston Castle to the Target Butts, and on to relic No. 2 showed the top of this structure to be 22·70 feet above O.D.[2] The hydrographer to the Admiralty kindly gave the height of the local Admiralty chart datum in relation to two bronze plugs at Porthcawl harbour. These were levelled to an Ordnance bench mark, and showed the local chart datum to be 14·3 feet below Ordnance datum. Mean High Water Springs at Porthcawl is 29 ft. 4 in. above Admiralty datum, and is therefore 15 ft. 1 in. above Ordnance datum. Thus the top of remnant No. 2 was 7 ft. 7 in. above Mean High Water Springs on the beach beyond, and the series varied from 13 ft. 6 in. in the west, through 6 ft. 5 in. at their lowest (the westward extremity of No. 2), to 8 ft. 1 in. in the east, above this tide.

This variation in height, together with the state of our knowledge of wave action, particularly during storms and abnormal tides, made it impossible to base any conclusions on the remnants

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[1] i.e. 24th March, 1932.

[2] Owing to the absence of any bench mark within the area it was impossible to carry through to tie in the final reading. In order to ensure, while crossing the sand-hills, that no loss of height occurred at the frequent changes, on steep slopes with loose surface, large stones were carried from change to change.

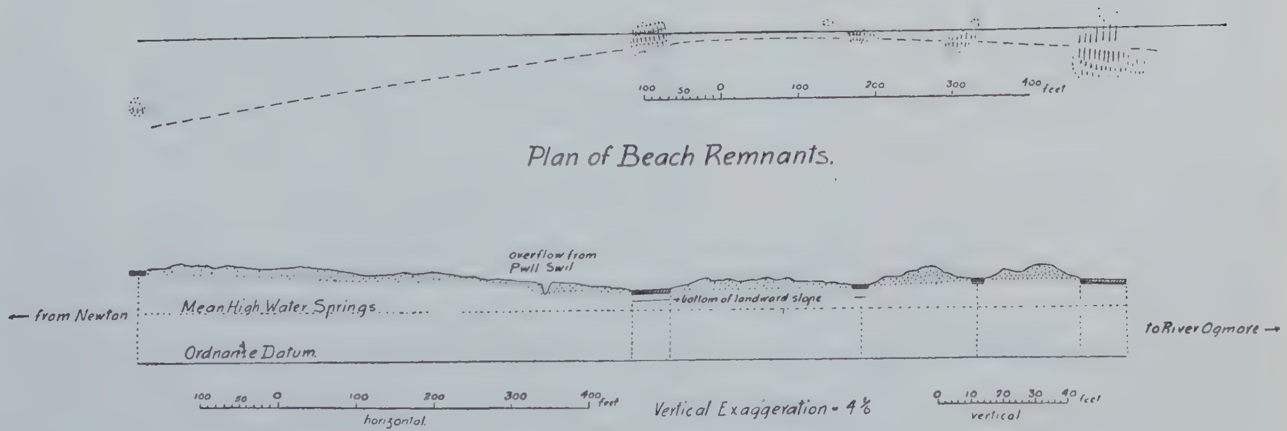

FIG. 4.—Longitudinal Section.

as a whole. Fortunately remnant No. 2 contained a bed, marked No. 2 in the section, the composition and form of which showed it to represent the tip of average wave action at the time of its formation.[1] The tip of this bed was 5 ft. 2 in. above Mean High Water Springs, and could therefore have been formed when the relative levels of land and sea were identical with those existing to-day.[2]

This old shore-line, although it cannot be dated, must have come into existence after the rocky part of the coast to the west had assumed much of its present form following the so-called Neolithic subsidence, and must have been evolved when the relative levels of land and sea in the neighbourhood were almost, if not exactly, those in existence to-day. Since it is not probable that a subsequent double oscillation could have returned land and water so exactly to their previous levels, no change could have taken place in these levels since the beach was formed.[3]

The "Tinto Glacier" and some Glacial Features in Clydesdale.

By D. L. Linton, M.Sc., University of Edinburgh.

TINTO HILL, by reason of its height, its massive but shapely form, and its splendid isolation, dominates the whole of middle Clydesdale. It forms an east-west ridge of tadpole-like outline—massive and lofty towards the eastern end and tailing away towards the western extremity, the only point at which it makes contact with the neighbouring uplands. On the east it rises directly from Clydesdale, where its lower slopes pass into a drift-mantled bench, which is from 1 to 2 miles in width. The lower and flatter portions of this bench are covered by a sheet of sand and gravel 30 or more feet above the Clyde flood-plain. The gravel spread extends into the broad open valleys which isolate Tinto to north and south, and is there undergoing dissection by the Glade Burn and Garf Water. The dissection is, however, hardly more than begun, and the undulating and sometimes moundy character of the surface of the gravel sheet reflects the uneven nature of the original deposition. Rising sharply from this surface are certain striking mounds and ridges which have received some mention in geological literature under the name of the Thankerton Kames. They were first noted by Sir Archibald Geikie (2, p. 44),[1] and later described, with a map indicating their extent and distribution, by Professor Gregory (3, p. 474). They have been further discussed by Professor Charlesworth (1, pp. 31–37), who is unable to accept Professor Gregory's interpretation of the facts. More recently they have been mapped by the officers of the Geological Survey (4), together with the better-known Kames of Carstairs, and in this connection a note by Dr. M. Macgregor on the latter (6) is of some interest.

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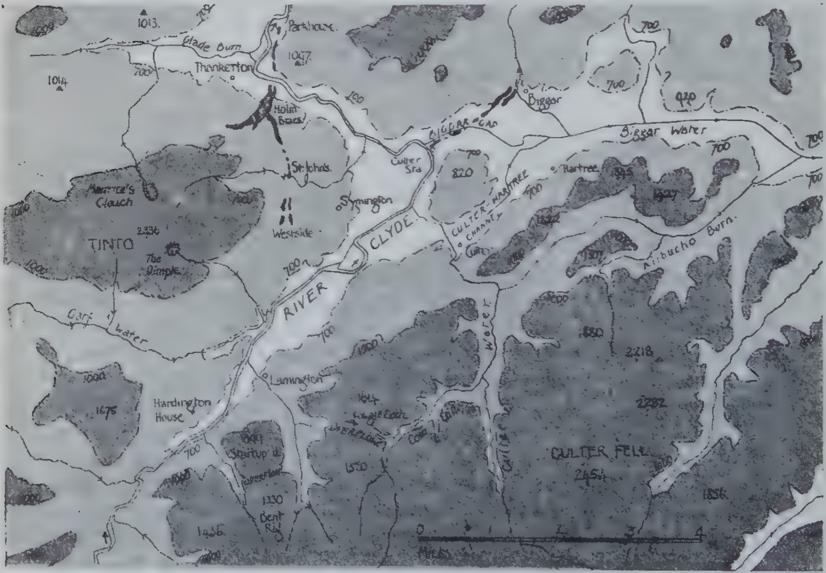
[1] The form of the bed shows that it had not been subjected to erosion since its formation.

[2] This conclusion has since been corroborated in a very conclusive way. A high tide occurred during 23rd–26th March, 1932, and on the 24th broke through the littoral dune to the seaward of remnant No. 2, and almost completely submerged it.

[3] This beach could not have been formed after 1578 for a manuscript map of the area bearing this date (*The Storie of the Lower Borowes of Merthyrmawr*, edited Randall and Rees) is sufficiently accurate near the river to show that the coast-line in its neighbourhood still occupies much the same position.



The diversity of opinion that has been held regarding the formation of these deposits arises from the difficulty that has been experienced in deciding which ice-mass is to be held responsible for them. Gregory postulated two such "glaciers", the "Tinto Glacier" and the "Clydesdale Glacier", and, arguing from their internal constitution, ascribed the kames to the activities of the former. Charlesworth accepted both these postulated ice-masses, and to them added a third—the Northern Ice originating in the Highlands of Dumbarton and Argyllshire. He endeavoured to trace their several limits, and assigned certain moraines to the " Tinto Glacier ", certain other deposits to the " Clydesdale Ice " ; he indicated the points of separation of these ice-masses from the margin of the Northern Ice, and gave reasons for regarding the latter as being responsible for the Thankerton Kames.

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[1] The figures in parentheses relate to References at the end of the article.

It is not proposed to rediscuss here the evidence which the form, distribution, and composition of the kames provides upon these points. The intention is rather to inquire whether, before we attribute to these respective ice-masses, moraines, " glacieluvial " kames, or other deposits, or attempt to define the points at which they separated, the validity of their existence has been satisfactorily established ; whether, indeed, it is necessary to pre-suppose the presence of these three ice-bodies in this area.

In pursuing this inquiry we may take advantage of evidence not used by either Gregory or Charlesworth—namely, that offered by a study of the land-forms of the surrounding region.

One can readily understand how the idea of a " Tinto Glacier " arose. For on the basis of the impression formerly current, that mere height alone is sufficient to ensure the accumulation of a glacial covering, Tinto should certainly have nourished its own ice-mass. Rarely does the level of the Southern Uplands Plateau rise above that of the summit of Tinto, but that the former nourished an active ice-cap is generally admitted. But summit-level alone is not enough, and when examined on the ground it becomes abundantly plain that Tinto never nourished any independent, moving ice-bodies. On the one hand it has not the massive bulk and extensive summit area upon which to support a broad névé field which would discharge by active ice-tongues after the manner of the Icelandic Jökulls ; and on the other, its flanks are not scarred by corries in which glaciers of Alpine type might have taken their origin. Perhaps the nearest approach to a corrie that can be offered is the deep combe known as Maurice's Cleuch, a conspicuous feature on the northern side of the hill. It is essentially a nivation hollow, with a markedly V-shaped cross-section, and almost rectilinear slopes which flare outwards and become convex in their upper parts. The Cleuch Burn rises in a similar, but less well marked, depression, while on the southern side the Dimple is again similar, but rather smaller. It is noteworthy, also, that none of these features in the least affects the slopes above 1,800 feet, a level still 500 odd feet below the summit. Regarding the hill as a whole, and ignoring for the moment these minor features, its smooth flowing outlines and graded slopes speak clearly of a history of long-continued normal erosion, and, indeed, certain slopes and spurs give the clearest indications whereby some of the phases of that erosion history may be reconstructed. Finally, in sharp contradiction of the idea of a " Tinto Glacier " is the manner in which the Boulder Clay mounts up the northern slopes to considerable heights, strongly suggesting that during the readvance postulated by Charlesworth, Tinto was largely over-ridden by

Northern Ice. It is, therefore, suggested that the "Tinto Glacier" should be dismissed from geological literature, and that Gregory and Charlesworth were alike mistaken in believing it to have had any real existence.

But there is reason to believe that the Clydesdale Ice, though its actual existence is not in question, nevertheless has no place in this picture. Charlesworth himself has demonstrated that the presence of the Northern Ice in this district was due to a re-advance which carried its margin to the Southern Uplands Boundary. Of this there is objective evidence in the moraines with northern rock fragments which occur, for example, south of Biggar between Culter and Hartree. But the evidence of the land-forms suggests that at this phase of maximum re-advance of the Northern Ice, the Southern Ice had retreated well into Clydesdale, and any sympathetic re-advance that it may have undergone still left the ice-margin south of Roberton.

This evidence is comprised in the series of overflow channels by which the waters impounded in Clydesdale by the margin of the Northern Ice escaped into the valley of the Biggar Water, and so to the North Sea by way of Tweeddale, which is generally admitted to have been ice-free at this period. The highest of these spillways occurs 1½ miles south of Lamington Church, between Startup Hill and Bent Rig, and carried water from the major pro-glacial lake in Clydesdale to a small lake in the valley of the Lamington Burn. Its intake was probably above 1,200 feet at first, and was abandoned at 1,140 feet. It implies that a tongue of Northern Ice pressed into Clydesdale far enough to block the valley of the Lamington Burn to a height of at least 1,150 feet, which incidentally tells us that the ice was practically 500 feet thick at its margin.

From the lakelet on the site of the Lamington Burn the waters escaped by the spillway which contains the artificially dammed Cowgill Loch, into Cow Gill itself, and so by the valley of the Culter Water into the broad, flat-floored through valley which leads to the Kilbucho Burn and so to the ice-free Tweed. The intake above Cowgill Loch was originally at about 1,150 feet and was finally cut to a level about 100 feet lower. This channel and that behind Startup Hill were in use at the same time, but they differ in character. The floor of the latter pitches downhill fairly steeply and ends abruptly at the former lake level; the melt waters passing through the Cowgill channel, on the other hand, found themselves in an empty valley, and have modified its form throughout its length. A flat-floored channel was opened out and the valley sides undercut for 200 feet or more, giving most impressive interlocking rock spurs and bluffs.

The inference that is to be drawn from these features is clear. At the period of maximum re-advance, as marked by the southernmost terminal moraines of the Northern Ice, a lobe of the latter pressed into Clydesdale as far as the site of Hardington House, but it nevertheless failed to make contact with the ice-tongue descending from the Southern Uplands.

The later channels are not so important from the point of view of the present discussion, but some mention of them is desirable to complete the account. As soon as the Northern Ice began to withdraw from the Southern Uplands margin, the old pre-glacial valley of the Culter Water, which runs north-eastward from Culter village, at once became uncovered, and the impounded waters in Clydesdale took this direct route to Tweeddale, and the pro-glacial lake disappeared. No over-deepening occurred, as at Cowgill, though there may have been some removal of the drift which mantles the sides. Aggradation built up a flat floor which is more than 500 yards wide at the western end, but narrows eastward to about 75 yards just beyond Threepland, and emerges upon the valley of the Biggar Water at Hartree. It falls from 690 feet to 650 feet in 2 miles.

The last channel connecting the Clyde and Tweed systems is the well-known Biggar Gap. At some time not long before the glaciation it had been abandoned by the Upper Clyde as a result of capture by streams belonging to the Lower Clyde system (5). During the glaciation it was somewhat deepened by the eastward passage of ice through it, and coated with drift. As in the case of the Culter-Hartree channel, aggradation occurred, building up a flat floor which declined from 670 feet at the western end near Netherton to 650 feet at the eastern end at Boghall. It is reasonable to believe that both these channels continued to be in operation side by side, until the pro-glacial Lake Clyde described by Charlesworth found lower outlets to the Forth drainage north of Airdrie (1, p. 42). The lake level then fell practically 200 feet, and the course of the Clyde above Lanark was re-established and incised below the level reached in the aggradation phase, giving the present terrace features at Culter Station.

We may conclude, then, that if the several sand and gravel accumulations which rise above the general level of the drifts of this part of Clydesdale are to be referred to the last visitation of the district by ice—and they can hardly belong to an earlier phase, for if so the later ice advance would have swept them away—they are all to be associated with the Northern Ice. Charlesworth has referred certain "heaps of sand and gravel near Lamington" to the retreating Clydesdale ice-tongue (1, p. 32), but no deposits in that district are known to the writer which are inconsistent with the conclusions here advanced.

With Charlesworth's views as to the origin of the Thankerton Kames, the writer is thus in fullest accord. They comprise two distinct features, both of which Charlesworth recognized in 1925. The first is essentially *marginal* in its relation to the ice, and comprises the series of mounds and ridges that extends as a crescent with its convexity to the south-east, from Sherrifflats at the southern end, through Holm Braes, across the Clyde by Quothquan Law Farm and Kames Wood, to terminate near Parkhouse. Since its deposition it has suffered no modification, save where the Clyde has breached it and cut down into the drift bench upon which it stands. The second feature is *radial* in relation to the ice-margin, and extends as a long, narrow, discontinuous ridge from the point where it makes contact with the first feature at Holm Braes, southwards by Muirhouse and St. John's Kirk to Westside Cottage. A third related feature which appears not to have received previous mention deserves to be noted here. Like the last it is a radial feature, and comprises a series of mounds and ridges extending through the length of the Biggar Gap. They are well marked on the outskirts of Biggar itself, where the mounds exceed 30 feet in height, and may be traced W.S.W. through Biggar Park, and thence along the southern side of the gap to Culter Station. Like the Symington feature it may perhaps be described as a beaded esker.

While one of the chief results of the present analysis has thus been to confirm, with some amplification, results that have been before geologists for the last half-dozen years, the writer is prompted to hope that the discussion as a whole will not be without interest. Particularly it is felt that less use is made than should be the case, of the technique of geomorphology in relation to purely geological problems, and the present discussion is offered, with the deference naturally due to the senior science, as an instance of the contribution morphological analysis can make. Gregory and Charlesworth, relying on the evidence which the several drift deposits themselves offered, were unable to dismiss the idea of a possible "Tinto Glacier", nor, to quote Charlesworth's own words, to assign "to each of these glaciers—the one issuing from Tinto, the other from Upper Clydesdale—their respective rôles". The evidence of the land-forms here supplements that of the surface geology and gives an unequivocal answer to both these questions. The "Tinto Glacier" never existed, and at the time when the Thankerton Kame was deposited, the Clydesdale Ice terminated well within the limits of the Southern Uplands. The situation is thus simplified and the interpretation of the geological evidence is rendered at once more easy and more certain.

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(3) J. W. GREGORY. "The Kames of Carstairs," *Scot. Geog. Mag.*, xxxi, 1915, 465–476.

(4) *Geological Survey of Scotland*, Sheet 23, 3rd edition, 1929.

(5) D. L. LINTON. "On the Former Connection between the Clyde and the Tweed," *Scot. Geog. Mag.*, in the press, vol. l, 1934.

(6) M. MACGREGOR. "The Carstairs District," *Proc. Geol. Assoc.*, xxxviii, 1927, 495–9.

The localities referred to in this article are all to be found on Sheet 79 (Lanark), O.S. Scotland, 1 in./mile, Popular Edition.

REPORTS AND PROCEEDINGS.

BRITISH ASSOCIATION, LEICESTER 1933.

Abstract of Paper read in Section C.—Geology.

Mr. Francis Jones: "Further notes on the petrology of the igneous rocks of Leicestershire."

The intrusive rocks of the Leicestershire-Warwickshire area group into five divisions, viz. (1) Diorite-Granophyres of Charnwood, (2) Microdiorites of South-West Leicestershire, (3) Mountsorrel Granite complex, (4) Camptonite-Diorites of Nuneaton, (5) Intrusions into Caldecote series. Chronological or genetic correlation is difficult. The age of the last two groups is known within limits; that of the granophyres is established with the fifth group. The "camptonites" contrast with all the others not only as regards basicity, but in being concordant intrusions of "wet" magma.

Structural study of the Mountsorrel complex confirms the evidence of its mineral freshness that it is a late intrusion. The isolated outcrops of the non-granophyric diorites of the south-west make special difficulty in interpreting their positions in the sequence. Joint phenomena suggest structures excluding contemporaneity with the granophyres. Mineralogically they "fit in" between the granophyres and the granite. They show diversity of detail mainly in regard to hydrothermal alteration and to the occurrence of epidote. The Croft-Huncote rock is of especial interest in regard to the former. Here albitization is advanced: analcite and laumontite have been developed as vein minerals, and prehnite occurs within the altered rock. The phenomena developed resemble those described by Gilluly in his paper "Replacement Origin of the Albite Granite, Sparta, Oregon" (*U.S. Geol. Sur. Prof. Paper*, 175-C).

REVIEWS.

PROVISIONAL GEOLOGICAL MAP OF TANGANYIKA, WITH EXPLANATORY NOTES. By E. O. Teale. Geol. Survey Department Bull. No. 6. pp. 34, 1933. Dar-es-Salaam. Price *Shs.* 4.

COVERING an area of some 360,000 square miles, this colour-printed map, on a scale of 1 in 2 millions, contains many large blanks, but constitutes a distinct advance on previous compilations; mineral deposits are marked, chief of which are gold, diamonds, salt, tin, and mica. The solid geology consists mainly of ancient sediments, volcanics, and crystallines, with subordinate Karroo, Jurassic, Cretaceous, and Tertiary beds. Conspicuous is the chequer-board pattern made by the Rift Fault system with its dominant N.E. and N.W. trending fracture lines. There is a particularly useful summary of the geology of the region.

A. D. T.

SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN AND THE MUSEUM OF PRACTICAL GEOLOGY FOR THE YEAR 1932. Part I, pp. 1–98, price 2*s.*; Part II, pp. 1–142, plates 1–10, and numerous text-figures. Price 3*s.*

THE Report of the Director naturally refers to the impending move of the Survey to new quarters in South Kensington, and the energies of many of the officers will be directed in the immediate future to the preparation of material for exhibition in the new Museum. The records of work given in Part I call for little comment, though it is perhaps worthy of note that all the " mussel " zones from *Carbonicola ovalis* to *Anthracomya phillipsi* have been recognized in the Sanquhar Coal Basin.

Part II, on the other hand, contains as usual many features of interest and importance; foremost amongst these must be placed Sir John Flett's little memoir on " The Geology of Meneage ". In this district as the result of Miss Hendricks's discovery of *Dadoxylon* and other fossil plants in beds previously considered to be of different ages, our ideas concerning the stratigraphy and structure of the region have to be entirely revised. There has been recognized a definite " crush zone ", the Meneage Crush Zone, forming the northern boundary of the Lizard rocks. This, Sir John believes, consists of a vast mass of Pre-Cambrian and Palaeozoic rocks (Lizard Schists, Ordovician, Silurian, Devonian, and possibly Carboniferous) driven northwards and broken up by late Carboniferous Hercynian movements. A somewhat longer memoir, dealing with the geology of the Kent Coalfield, is also of interest; this consists of three parts: (1) " Sequence and Structure," by H. G. Dines; (2) " Fossil Flora," by Dr. R. Crookall; and (3) " Fauna of the Coal Measures," by Dr. Stubblefield.

G. L. E.

In describing a new well and boring in the Gault near Wicken, Mr. Dixon summarizes previous work on the Cambridgeshire Gault. Unfortunately, in discussing the published record of " *Ammonites interruptus* " [= *Hoplites dentatus* (J. Sowerby) in modern terminology] with " *Inoceramus sulcatus* " from the Gault of Upware, he has not consulted the fossils on which the records are based; and claiming (rightly) that they imply an " incompatible association ", suggests that " *Amm. interruptus* " should be rejected as a misidentification. Since *I. sulcatus* is an Upper Gault form, he therefore concludes that the Lower Gault is missing at Upware.

Examination of the specimens preserved in the Sedgwick Museum shows that the *Inoceramus* fauna includes the long-ranged species *I. concentricus*, while *I. sulcatus* is definitely absent; and that the ammonite fauna from Upware is a typical assemblage of the Dentatus Zone (Lower Gault). Dr. Spath (who has recently examined the specimens) has recognized *Hoplites dentatus*, *H. bonarelli* Spath, *H. paronai* Spath, *H. persulcatus* Spath, and *H. similis* Spath, all common forms in the Dentatus Zone; and he considers that there is no evidence that any other zone is present. The faunal evidence thus definitely points to the presence of the Lower Gault at Upware.

The account of the new section is a welcome addition to our scanty knowledge of the badly exposed Cambridgeshire Gault.

Miss Elles contributes a valuable discussion of the principles of zoning in the Lower Ordovician faunas: the age of the Skiddaw Slates is discussed, and one new species is described.

A. G. Brighton.

La Géologie et les Mines de la France d'outre-mer. pp. 604, with 2 plates (folding maps), and 38 figures. Paris: Société d'Editions Geographiques, Maritimes et Coloniales, 1932.

THIS handsome volume is the outcome of a movement by the French Government and certain important industrial interests towards the long-neglected development of the mineral resources of the overseas dominions of the Republic. The Government having made a large grant for the purpose, a powerful syndicate was formed, under the name of *Comité d'Études minières pour la France d'outre-mer*: this in its turn set up another body, the *Bureau d'Études géologiques et minières coloniales*, to act in conjunction with public departments in the investigation. Among other means adopted was the arrangement of courses of lectures at Paris in the winter of 1931–2. These lectures are reproduced in the present volume. The whole scheme seems to form an admirable and far-sighted preparation for the much-hoped-for industrial revival when, if ever, it does come.

All the lectures were given by first-class authorities on their respective areas, and while they are naturally for the most part compilations, and not original work needing criticism in a review, nevertheless they form a most useful summary of the present state of knowledge of the geology of the vast French colonial empire. Naturally, most of the lectures deal with Africa, about 350 pages out of 550 being devoted to that continent and Madagascar (it was a bit of a shock to the reviewer to find that Kerguelen is a French possession); nevertheless French Indo-China, New Caledonia, and French Guiana are quite large and important, while the number of smaller dependencies is very considerable, including the mandated territories of the Levant.

The list of contributors contains many names well known in this country, and as is only to be expected, Monsieur A. Lacroix, with his unrivalled personal knowledge of the geology of the French colonies, has played an important part in the scheme: he is directly responsible for the sections on the older rocks of Madagascar and for the geology of French Guiana, and it is indicated in the introduction that he has rendered invaluable help in the whole organization of the project.

The book is abundantly provided with indexes (over thirty pages). In many cases the French spelling of geographical names is rather disconcerting to English readers, who may find a difficulty in running down familiar names in this guise. And finally, it may be asked, why will French publishers insist on putting the table of contents at the end of the volume instead of at the beginning, which is surely its natural place ?

The authorities concerned are greatly to be congratulated on the production of this invaluable work.

CORRESPONDENCE.

LATERITE.

Sir,—I have seen the correspondence in your Magazine, Vol. LXX, by H. B. Maufe (p. 144, March, 1933), J. B. Scrivenor (p. 191, April, 1933), and P. Lake (p. 240, May, 1933) on the subject of Buchanan's Laterite.

It may therefore interest you to know that Dr. L. L. Fermor, Director of the Geological Survey of India, has instructed me to visit the places which Buchanan mentions in his travels of 1800–1.

I will make this investigation in November and endeavour to clear up the whole question so as to give those geologists who are familiar with the Malay Peninsula and elsewhere data for correct judgment.

Cyril S. Fox.

THE ELEVATION OF THE MARQUESAS ISLANDS.

Sir,—Will you kindly allow me space to correct an error that has found its way into my paper on the "Geology of the Marquesas Islands" (Bernice P. Bishop Mus., *Bull.* 68). On page 20 I described as limestone an outcrop of white rock at an altitude of 1,300 feet on the island of Nukahiva. I did not myself visit the outcrop, but it was described to me by Lieut.-Col. H. J. Kelsall, a member of the scientific staff of the "St. George" Expedition, who passed by it. Colonel Kelsall did not collect a specimen, as he had previously brought me many samples of white materials only to have them rejected as decomposition products of lava. Later, however, he brought me a specimen, purporting to come from the outcrop, given to him by a resident of many years' standing, Père Siméon Delmas. Immediately on receiving this I tested it with acid, when it effervesced freely, and on my return home I found it to be a fine-grained foraminiferal limestone, exactly resembling chalk.

Recently I heard from Mr. A. M. Adamson, of the Pacific Entomological Survey, that he too had noticed the white rock and had received a specimen of it from Père Siméon, as well as others collected from the outcrop by Mr Robert MacKittrick. These had been examined by Professor Howel Williams, who found all to be decomposition products of some volcanic rock.

As the matter had a bearing on the question of the uplift of Nukahiva, I wrote to Père Siméon, who very kindly sent me further specimens. These are all a decomposition product of a lava, without any trace of calcareous material. Père Siméon very generously accepts the responsibility for having sent me a wrongly-labelled specimen, but is unable to explain its origin. It would appear, therefore, that there is no evidence of the presence of any uplifted limestone on Nukahiva.

Since beginning this letter I have received a copy of Professor Howel Williams's " Geology of Tahiti, Moorea, and Maiao " (Bernice P. Bishop Mus., *Bull.* 105). As regards Maiao, which both Professor Williams and I have visited and described, we are in almost complete agreement. Professor Williams, however, discusses the evidences of elevation and subsidence in the Marquesas Islands and especially criticizes my view that some of them have been uplifted to the extent of 2,000 or 3,000 feet. He has not actually visited this group, but he is not the first to publish views on the geological history of Pacific islands without seeing them. My own conscience is not quite clear in this matter, but I *have* visited the Marquesas Islands. A perusal of my paper will show that I depended for evidence of uplift, primarily, not on the " limestone " of Nukahiva nor on the scattered molluscan shells on the higher ground, which may indeed have been carried up by natives, but on the presence of high plateaux on some of the islands. The plateau at Nukahiva was described to me by officers of the *Service Topographique*, who were carrying out a topographic survey of the island, as a peneplain at 800 metres. I never set foot on it, but from a ridge which rises almost to the same height in the south-western part of the island I observed the even, horizontal skyline, which differs markedly from the castellated skyline characteristic of so many Pacific islands. I worked for several days on the southern plateau of Hivaoa, and if Professor Williams could see it I have no doubt that his conclusion would be the same as mine. The interfluves are all bevelled at exactly the same height, and all have broad and remarkably level summits. From the western edge of the plateau, 1,300 feet above Taa-hu-ku, one can look eastward for eight or nine miles, one's line of sight just skimming the surface of the flat tops of the interfluves all the way. From its southern margin the plateau slopes gently upwards with an even gradient to a height of 1,600 feet at the foot of the central ridge, which rises sharply some hundreds of feet higher. Such a level surface could only have been formed either just above, or more probably just below, sea-level. It is a very remarkable feature, and any topographic map that fails to show it is inaccurate. The occurrence, reported by Professor Williams, of an undoubted marine deposit at a height of 250 feet above sea-level on the island of Tahuata is certainly in no way opposed to my view, nor does it limit the amount of uplift to this figure. It is interesting, as previously little definite evidence of uplift had been found on this island.

Professor Williams agrees with me that there has been extensive faulting, leading to the disappearance of parts of some of the islands. This involves either a downthrow of at least 2,000 or 3,000 feet on one side of a fault, or an upthrow of similar amount on the other side. The latter alternative seems to explain all the known facts. That such faulting has taken place does not support Professor Williams's conclusion that the area is a relatively stable one.

Professor Williams questions too my method of estimating the amount of the submergence suffered by the Marquesas Islands at a later stage in their history. I assumed that originally the valleys were " V "-shaped, and the slopes of their sides were the same as they are now; then, the width of an embayment being known, a simple calculation will give its rock-bottom depth. The first assumption is completely justifiable, as, except where they have been partially filled in with deltaic deposits since submergence, the valleys are still " V "-shaped and the drainage cannot have been more mature before submergence than it is now. Steepening of the valley sides since submergence is unlikely, as the tendency of subaerial erosion will have been to lower their gradients. The embayments may have been slightly widened by marine erosion, but as far as possible I allowed for this in my calculations.

I reckoned the amount of submergence of Hivaoa at 600 feet, and this is more likely to be an under- than an over-estimate. The post-glacial rise in sea-level can account for only a part of it.

L. J. Chubb.

University College,
London.
10th October, 1933.

BRECCIAS IN THE WARWICKSHIRE COALFIELD

Sir,—In a paper recently published in this Magazine,[1] the author makes a brief reference to a publication [2] of mine which may give, unintentionally, a misleading impression of some of the conclusions come to in the course of my work among the Red Rocks of the Midlands. He says (p. 474) that I stated " that the unconformity below the (Clent) breccia is greater in magnitude than that between it and the Bunter ". What I said was that the break between the Clent breccias and the overlying Bunter in the Birmingham area is generally not so pronounced as that at their base. I was dealing specially in that paper with the lithological evidence, and did not mean that the unconformity at the base of the Bunter in the Midlands generally is of less magnitude than that at the base of the Clent Beds. Still less did I mean to imply that the unconformity at the base of the Keuper is less, for the latter is seen to be unconformable to the Bunter in some places in the Midlands. As to whether the Clent Beds are of Carboniferous or Permian age, it is obvious that in the absence of fossils there can be no satisfactory proof. But I have always felt that the onus rests with those who link them with the Carboniferous to show good evidence for removing them from the Permian. In the Birmingham area, the distinctive composition and source of these deposits, and the pronounced unconformity at their base, seem to me to justify in the meantime their retention in the Permian.

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[1] F. W. Shotton, " New Evidence on the Origin of Breccias and Conglomerates in the Warwickshire Coalfield," Geol. Mag., October, 1933.

[2] W. S. Boulton, " The Rocks between the Carboniferous and the Trias in the Birmingham district," *Quart. Journ. Geol. Soc.*, lxxxix, 1933.

W. S. Boulton.

40 Oakfield Road,
Selly Park, Birmingham.
6th November, 1933.

ON THE PREPARATION OF GEOLOGICAL MANUSCRIPTS

Sir,—May I be permitted to welcome the Editor's remarks on the preparation of Geological Manuscripts and at the same time to offer a few comments.

As a palaeontologist, I am gratified to learn that " palaeontologists do seem to know their job " ; still the Editor's difficulty in understanding when the name of the author of a species should be enclosed in parentheses may possibly be the fault of those writers. The rule simply is that when a species has been transferred from the genus in which its original author placed it to another genus, then, and then only, is the name of its author placed in parentheses.

Some writers make a fetish of the author's name attached to a species name. The main reason for giving it at all is to avoid confusion with possible homonyms, and it may for the same reason be necessary to give the date as well. In any case the information is helpful to a reader who may wish to look up the species. But once this information has been given, it is useless pedantry to keep repeating it throughout a paper.

The principles laid down for the use of capitals in the names of rocks, minerals, and stratigraphical divisions seem exactly to meet the case. One occasionally meets with a use of the word " carboniferous " different from any of the examples given. When a rock of any age, e.g. Miocene, contains coal, it may therefore be called a carboniferous rock, although it does not form part of the Carboniferous system.

Coming now to the method of quoting previous publications, I ask leave to draw attention to the various Reports of the British Association's Committee on Zoological Bibliography and Publication, which in this respect apply equally to palaeontology and geology.

In general the method now proposed for the Geological Magazine agrees with that consistently recommended by the British Association Committee. An important difference, however, comes in the position of the year of publication. This the Committee considers should immediately follow the name of the author so that in any "List of papers cited", while the authors' names appear in alphabetical order, if there is more than one paper by a single author, those papers are placed in order of date, and thus are referred to without difficulty. It takes much longer to find the date of publication when it is intercalated between the volume number and the page number. Such a position is also quite illogical, and is liable to lead to confusion between "Jahrgang" and date.[1]

It is hard to agree that the date of publication should ever be omitted, even from the "Summary of Progress of the Geological Survey". It is quite possible for a new species to be first described in the "Summary of Progress", and the precise date of its publication may be a matter of considerable importance.

One would like to suggest that in references to literature the volume number should be given in capital romans, reserving small romans for the plate numbers. The number of a series should be placed between brackets in Arabic figures before the volume number, and the number of a part, if necessary, should be placed, also in brackets, after the volume number.

It is laid down in your article that in quoting titles "capital letters should be copied exactly from the original". At one time I tried to follow this instruction, but eventually found it impracticable owing to the great diversity of treatment. It was pointed out to me that, since the capitalization of titles generally represents the fancy of the compositor, there was no virtue in following it unless one were producing a detailed bibliography in the proper sense of the word.

The abbreviations given in "Geological Literature added to the Geological Society's Library" are undoubtedly good, but attention should be drawn to the method followed in the "List of Scientific Periodicals" drawn up with the help of the British Museum. Finally, may I venture to hope that the Geological Magazine will make the very slight modification needed to enable it to fall into line with the methods of reference recommended by the British Association Committee, and adopted by an ever-increasing number of scientific publications in all parts of the world.

F. A. Bather.

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[1] Dr. Bather is here referring to bibliographies, whereas the remark in the original article was intended to apply only to footnotes. The arrangement of lists of references was not discussed.—Ed.

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